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THE ELECTRON THEORY OF MAGNETISM[1]

EVER since the time of Faraday it has been known that all varieties of matter can be grouped in three classes on the basis of magnetic behavior, ferromagnetic, paramagnetic and diamagnetic.

It would be far too much to claim that the electron theory has as yet given anything like a complete account of the phenomena witnessed in connection with these three types of magnetism; but it is the only theory proposed which has been in any way satisfactory and which appears to hold out any hope for the future.

In accordance with the plans of this symposium I shall restrict myself to a consideration of the more general aspects of the theory and its simplest applications. For the sake of logical completeness I shall have to refer to many matters well known. The extension of the theory and its application to more special and complex cases, in so far as they can be handled on this occasion, will be treated by my colleagues.

The first electrical theory of ferromagnetism was proposed by Ampère just about one hundred years ago. On the basis of his own experiments on the behavior of electric circuits and magnets, and on the assumption, already justified, that magnetism is a molecular and not a molar phenomenon, he concluded that the molecule of iron is the seat of a permanent electrical whirl and thus essentially a permanent magnet with its axis perpendicular to the whirl. When the iron is fully magnetized, all the whirls are oriented alike, and

[1] A paper read as a part of the symposium on recent progress in magnetism held at the joint meeting of the American Association for the Advancement of Science, Section B, and the American Physical Society, December, 1920. Revised, January, 1921.

the magnetic moment of the mass of iron is the sum of the moments of the elementary molecular magnets. Ampère undoubtedly considered that in a neutral mass of iron the molecular magnets are turned indiscriminately in all directions, but he did not enter into any discussion of the process by which their axes are made parallel by the field during magnetization, nor did he consider the nature of the electrical whirls themselves.

Ampère was the grandfather of the electron theory of magnetism. Wilhelm Weber was its father. In 1852 Weber[2] published a paper in which he developed a theory which, slightly modified by Langevin,[3] is still perhaps the most widely accepted theory of diamagnetism, together with a theory of ferromagnetism which formed the starting point for the well-known theory of Ewing. Weber adopted the molecular whirls of Ampère, but assumed in addition that these whirls, always present in the molecules of magnetic substances, are also present in the molecules of diamagnetic substances when placed in a magnetic field. Further, he took the very important step of attributing mass or inertia to the electricity in the whirls, and he assumed that the electricity moves as if in fixed circular grooves in the molecule, so that each whirl maintains its diameter and its orientation with respect to the rest of the molecule as if rigidly constrained. According to Weber's conception, a substance is paramagnetic or ferromagnetic when the molecule, or magnetic element, contains a permanent whirl, with a definite magnetic moment, and so tends to set with its axis in the direction of any magnetic field in which it is placed; and a substance is diamagnetic when the molecule contains one or more frictionless grooves, with the mobile electricity at rest before the creation of the magnetic field. Langevin merely substitutes electrons moving in fixed orbits for Weber's electricity in grooves; and assumes that in a diamagnetic substance more than one orbit exists in the molecule and that the orbits are so constituted and grouped that the magnetic moment of the whole molecule is zero in a neutral field.

[2] W. Weber's Werke, III., p. 555.

[3] *Ann. chim. phys.* (8), 5, 1905, p. 70.

In this case, which we shall consider in some detail, the complete molecule will suffer no change of orientation when introduced into a magnetic field, but the speed of the electricity in each orbit or groove will change on account of the electromotive force around the orbit or groove due to the alteration of the extraneous magnetic flux through it. Its magnetic moment μ will thus increase (algebraically) by an amount $\Delta\mu$, which can readily be calculated. If e denotes the charge of electricity circulating in an orbit (whether as a single electron, or a ring of electrons, or a continuous ring), m the mass associated with the moving charge, r the radius of the orbit, H the intensity of the extraneous magnetic field, and θ the angle between the axis of the orbit and the direction of the field,

$$\Delta\mu = -\frac{e^2r^2H}{4m}\cdot\cos\theta. \qquad (1)$$

If we assume that there are N orbits per unit volume, all alike; and if we furthermore assume that all the orbits are perpendicular to the direction of the field (as they would be in the case of a saturated ferromagnetic substance) we get for the magnetic moment of unit volume, or the intensity of magnetization:

$$I = -\frac{e^2r^2NH}{4m} \qquad (2)$$

and for the susceptibility

$$K = I/H = -\frac{e^2r^2N}{4m}. \qquad (3)$$

If the orbits are not all perpendicular to the field intensity, but are uniformly distributed between all values of θ from 0 to π, as in an isotropic diamagnetic substance, we get instead of (3) the expression

$$K = -\frac{e^2r^2N}{12m}. \qquad (4)$$

If in this equation we substitute the value of e/m known for electrons in slow motion, and assume for a given substance such as bismuth values of N and r which appear to be reasonable from other physical evidence, we obtain from (4) values of K of the same order of magnitude as those found by experiment,

but the agreement is in general far from close. The equation requires that K should be independent of the temperature, unless e, m, r and N depend upon it. As is well known, the susceptibilities of many diamagnetic substances are independent of the temperature over wide ranges, while in other cases there is a marked dependence.

According to this theory also, effects of the same kind must exist in bodies which are ferromagnetic or paramagnetic superposed on effects of opposite sign, the resultant susceptibility being, as Larmor long ago pointed out, the sum of the two. The paramagnetic term may account for the variation of the resultant susceptibility with temperature in many diamagnetic bodies. From Weber's equation it may be shown that when $\theta = 0$

$$\frac{\Delta\mu}{\mu} = -\frac{eT}{m4\pi}H, \tag{5}$$

where T is the period of the orbit. If we assume that this period is that of sodium light, about 2×10^{-15} and that $H = 10^5$ (in excess of any intensity hitherto produced) (5) gives

$$\frac{\Delta\mu}{\mu} = -0.3 \times 10^{-3}, \tag{6}$$

so that the maximum diamagnetic effect is a very small part of the saturation effect in ferromagnetic substances. The fact that the intensity of magnetization of iron at saturation does not decrease appreciably even for great increases of intensity shows that $n = 1/T$ is very great.

From Weber's equations we may also calculate the change in frequency n of an orbit due to the magnetic field, and we find, after Langevin, but more generally,

$$\Delta n = -\frac{eH\cos\theta}{4\pi m}. \tag{7}$$

This may correspond in a way to the Zeeman effect in light, but gives a broad band instead of the sharp lines actually found, inasmuch as $\cos\theta$ has all values between -1 and $+1$.

It is unnecessary, however, to have recourse to electrons moving in orbits (or initially at rest and constrained to grooves) or to rotating electrified bodies, to explain the occurrence of diamagnetism, as has been shown by J. J. Thomson,[4] Voigt,[5] Lorentz,[6] and others, including very recently H. A. Wilson.[7] If a substance contains electrons either at rest or in plain rectilinear motion due to thermal agitation, and a magnetic field is created, an electrical intensity will evidently be developed with a curl equal to the negative rate of increase of the flux density, which will cause the electrons to move in paths curved in such a way as to produce a magnetic moment opposed to the direction of the applied field; and as the field becomes steady curvature will be maintained by the action of the field on the moving electrons normal to their velocities. Calculation on this hypothesis gives susceptibilities of the same order of magnitude as those given by the Weber-Langevin theory. This form of theory has the advantages over the other of greater freedom from assumptions and of giving, when applied to the optical case, a Zeeman effect with sharp lines. Weber does not attempt to justify his assumption that in a molecule the diameters of his orbital grooves remain constant, and that in a diamagnetic substance the grooves maintain their orientations independent of the applied magnetic intensity. With respect to the diameters, however, Langevin has shown that the magnetic field will produce no alteration provided the law of force is not precisely that of the inverse cube, which is quite improbable.

We shall return to the subject of diamagnetism later.

The first detailed theory of paramagnetism was given for perfect gases by Langevin in 1905.[3] Following Langevin, I shall begin with a gravitational analogue. Let us consider an enclosure containing a gas at uniform temperature and let us suppose the gravitational field anulled. The density of the gas will then be uniform throughout the enclosure. If now the uniform gravitational field is brought into action every particle of gas will receive an acceleration downward,

[4] Int. cong. phys., 1900, vol. 3, p. 138.

[5] *Ann. der Phys.* (4), 9, 1902, p. 130.

[6] "The Theory of Electrons," p. 124.

[7] *Roy. Soc. Proc. A*, 97, 1920, p. 321.

and the up and down velocities of the molecules will exceed the horizontal velocities, until after a short time involving many collisions, a redistribution, as required by the principle of equipartition, will have occurred, in which the component squared velocities are equalized and the whole mass of gas has a temperature greater than before. If D_0 denotes the density of the gas at the bottom of the enclosure, D the density at any height x, m the mass of one molecule, r the gas constant for one molecule, T the absolute temperature and g the acceleration of gravity, we have the relation

$$D/D_0 = e - \frac{w}{rT}, \tag{8}$$

in which $w = mgx$ is the work necessary to raise one molecule through the distance x against gravity.

Now suppose each molecule to have a magnetic moment μ and imagine a vertical magnetic field applied throughout the enclosure instead of the gravitational field. The molecules will be driven to set themselves with their magnetic axes parallel to the magnetic intensity just as before the molecules were driven downward, and rotational velocities about lines normal to the field intensity will be favored, but thermal agitation will redistribute them as before until the law of equipartition is satisfied. If now θ denotes the angle made by the axis of any molecular magnet with the (vertical) magnetic intensity H, ρ the number of molecules per unit volume with their axes between θ and $\theta + d\theta$, and ρ_0 the number between 0 and $d\theta$, we have, by strict analogy with the gravitational case,

$$\rho/\rho_0 = e - \frac{mH(1-\cos\theta)}{rT}. \tag{9}$$

Starting from this formula we can readily calculate the total change produced in the magnetic moment of the gas (0 before the application of the field) and thus the intensity of magnetization I. If a is written for

$$\frac{mH}{rT} \tag{10}$$

we get the expression

$$I = N\mu\left\{\frac{e^a + e^{-a}}{e^a - e^{-a}} - \frac{1}{a}\right\}, \tag{11}$$

where $N =$ the number of molecules per unit volume.

When a is small, as it is except for very intense fields and very low temperatures, this equation becomes, with negligible error,

$$I = N\mu \cdot \frac{1}{3a} = \frac{N\mu^2}{3rT} \cdot H, \tag{12}$$

which gives for the susceptibility

$$K = I/H = \frac{N\mu^2}{3rT}. \tag{13}$$

The susceptibility is thus independent of H, and inversely proportional to T. So far as temperature is concerned it expresses the law of Curie, which holds for the paramagnetic gas oxygen over a great range of temperatures, and which holds over a great range in many other cases in which the molecular magnets are so far apart as not to act appreciably on one another.

Inasmuch as r is known, and as N is known for any value of T at known pressure, we can calculate μ from the observed value of K. We thus obtain for oxygen, reckoning from 0° C. and 760 mm. pressure,

$$\mu = \sqrt{\frac{3rTK}{N}} = 2.5 \times 10^{-20}. \tag{14}$$

Langevin's theory of paramagnetism is not an electron theory, as it has been developed without regard to the permanent electrical rotations assumed on this theory to account for the permanent magnetic moment of the elementary magnet. Nevertheless, it has rendered great services and has important relations to the electron theory.

Investigation of the behavior of *free* electron orbits, as distinguished from the fixed orbits of Weber, in a magnetic field, have been made by Voigt[5] and J. J. Thomson,[8] who independently, in 1902 and 1903, reached the conclusion that the existence, without damping, of such orbits in a substance would give it neither diamagnetic nor paramagnetic properties. The diamagnetic effects arising from change of velocities produced by the magnetic intensity are just balanced by the paramagnetic effects due to the change of orbital orientation. With suitable dissipation

[8] *Phil. Mag.* (6), 6, 1903, p. 673.

of energy, however, Thomson has concluded that paramagnetism may result, and Voigt that either paramagnetism or diamagnetism may result, according to circumstances. But the conceptions they have presented of the manner in which these results may be brought about do not seem probable, and have not gained wide acceptance.

Voigt and, after him, Lorentz and Gans,[9] have examined the behavior in a magnetic field of magnetic elements, or magnetons, consisting of homogeneous uniformly charged solids or symmetrical electron systems, in rotation, and have reached interesting and important conclusions.

One of the most important cases is that of a magneton which may be treated as a solid of revolution, with initial angular velocity greater than $eH/2m$ about the unique axis. In this case in accordance with classical electromagnetic theory, the rotation proceeds undamped about the unique axis, while it is damped about the other (equal) axes, and the action of the field on the magneton is as follows: When the field is applied, precession of the magneton's axis about the direction of the field begins, accompanied by nutation. The nutation is damped out by dissipation or radiation, and the precession is retarded for the same reason. Hence the direction of the axis of the magneton gradually approaches coincidence with the direction of the field, when it is in stable equilibrium. During this process the velocity of rotation diminishes slightly, the motion being affected as in the case of the electricity in Weber's molecular grooves.

If there are N such magnetons in the unit of volume, and if the demagnetizing and molecular fields and the upsetting effect of collisions are negligible, all the magnetons will ultimately become oriented with their axes in the direction of the magnetic field. In this case the moment of unit volume will be

$$I = \frac{eNC}{2m}\left(u - \frac{eH}{2m}\right), \qquad (15)$$

when e is the charge of the magneton, C its moment of inertia about the axis of permanent rotation, u its angular velocity about this axis, and H the intensity of the applied field.

[9] *Gött. Nachr.*, 1910, p. 197.

The first and principal term is entirely independent of H. The orientation is, of course, produced by the magnetic field, but only the time taken to arrive at the steady state is affected by its magnitude. The second term is a diamagnetic term, and arises from the fact that owing to the change of flux through the magneton during the process of its orientation its velocity is decreased, just as in the case of the Weber-Langevin theory.

In this case we have, except for the small diamagnetic term, which vanishes with the intensity, saturation for even the weakest fields; and we have less nearly complete saturation for stronger fields.

When collisions are not absent, a magneton's axis will be repeatedly deflected in its approach toward coincidence with the direction of the field, and the intensity of magnetization will not reach saturation; but it will increase with the field strength, being greater for a given field strength, the greater the mean time between collisions and the weaker the molecular and demagnetizing fields. Increase of temperature, shortening this time between collisions, and increasing their violence, will, if the magnetons remain unchanged, thus diminish the magnetization for a given field strength.

The precessional process described above is doubtless similar in a general way to the process by which in every case in paramagnetic and ferromagnetic substances the magnetons are aligned more or less completely with the magnetic field.

The exceedingly interesting ring electron recently proposed by A. L. Parson and extensively applied by him and others to a wide range of chemical and physical phenomena, is a special case of Voigt's magneton, and will be discussed by one of my colleagues.

Bearing in mind that, on the electron theory, the molecule or magneton must, with Voigt, be treated as a gyroscope and can not

execute true rotations,[10] such as Langevin assumed, except as very special cases of precession, Gans[11] has recently developed a general theory of diamagnetism and paramagnetism, proceeding in accordance with the methods of statistical mechanics. He assumes as his magneton a body rigidly built of negative electrons and placed inside a uniformly and positively charged sphere whose center is coincident with the center of mass of the electrons, and whose charge is equal in magnitude to that of the magneton, so that electrical actions do not have to be considered. The energy is assumed to be entirely electromagnetic.

For simplicity it is assumed that two of the principal (electromagnetic) moments of inertia are equal, but it is not assumed in general that the magneton is a body of revolution; thus the cross-section normal to the unique axis might be a square, and rotation about it subject to the effects of thermal collisions, instead of a circle, with rotation independent of such collisions.

The method of statistical mechanics is then applied to the two cases to be considered: first, that in which the magneton is not a body of revolution so that the rotations about the three axes must all be treated as statistical coordinates; and second, that in which the magneton is a body of revolution so that rotation about the axis of figure is not affected by collisions and can not be treated as a statistical coordinate.

In the first case it is found that the susceptibility is always negative, or the substance diamagnetic.

When the three principal moments of inertia are equal, the susceptibility is independent of the temperature and of the intensity of the magnetic field, which is the case with many diamagnetic substances.

When but two of the moments are equal, however, the susceptibility depends on both the temperature and the intensity in somewhat complicated ways. Fig. 1 shows the general relation between the susceptibility and the intensity according to Gans's theory, while Fig. 2 shows the type of curve found experimentally by Honda in many cases. The importance of carrying the measurements down

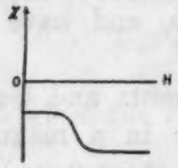

FIG. 1.

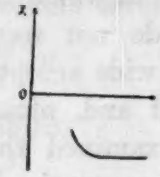

FIG. 2.

into weaker fields is manifest; and this has recently been done for bismuth and antimony by Isnardi and Gans,[12] who, working with pure materials, find no dependence on the field strength. As Honda suggests, the dependence on intensity suggested by his curves is probably due to the presence of iron, whose positive susceptibility, opposing that of the diamagnetic substances, decreases with increasing magnetic intensity. Curves obtained by Honda and Owen, and by Isnardi and Gans, are shown in Fig. 3.

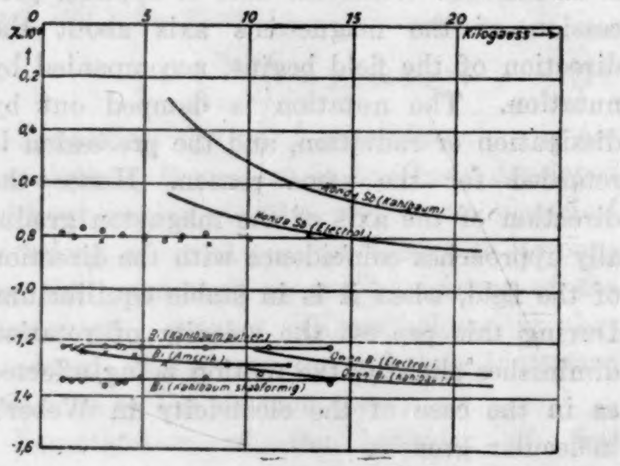

FIG. 3.

Fig. 4 shows the way in which, according to the theory, the susceptibility χ depends upon the absolute temperature θ, while the type of curve found in Honda's experiments is shown in Fig. 5. Little weight can be given the lower part of the theoretical curve, inasmuch as equipartition of energy and also absence of inter-molecular action were both assumed in its derivation, and it is improbable

[10] See also F. Krueger, *Ann. der Phys.* (4), 50, 1916, p. 364.

[11] *Ann. der Phys.* (4), 49, 1916, p. 149.

[12] *Ann. der Phys.* (4), 61, 1920, p. 585.

that either is true at low temperatures. There is a general agreement between theory and experiment. The trend of the experimental

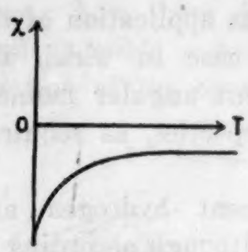

FIG. 4.

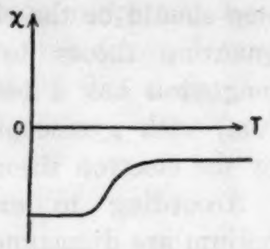

FIG. 5.

curve can not be explained by the presence of iron, as the positive susceptibility of the iron would become less with temperature increase.

We come now to the second case, in which the magneton has a true axis of figure and an essentially permanent angular momentum about this axis, and therefore a magnetic moment in the direction of this axis, unchangeable by collisions. On account of this permanent magnetic moment and angular momentum, paramagnetism results very much as in the theory of Voigt already presented; and on account of the slight diminution of this angular momentum in the magnetic field and on account of the rotation of the magneton about the other axes brought about or modified by the thermal agitation in accordance with the law of equipartition, diamagnetism results and is superposed upon the paramagnetism.

This diamagnetism does not appear in Langevin's theory, because instead of a permanently rotating magneton he assumed a permanent magnet without angular momentum about the axis except as produced by thermal collisions. Langevin, however, assumed that Weber's diamagnetism was superposed upon the paramagnetism, and this corresponds in part to the diamagnetism of Gans's theory.

Returning to the results of Gans's statistical treatment for the case of the magneton in permanent rotation about a unique axis, we find that the susceptibility is a function of both field strength and temperature. It may even be positive at lower intensities or temperatures, and negative at higher.

Isothermals for different temperatures θ between the susceptibility G and the magnetic intensity h are shown in Fig. 6, and isodynamics for different intensities h between the susceptibility G and the temperature θ are

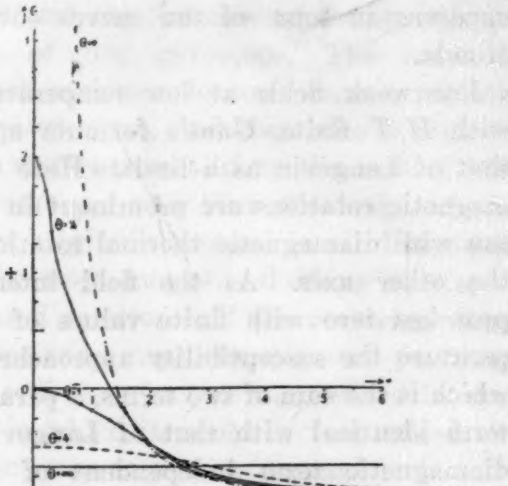

FIG. 6.

shown in Fig. 7. Thus while diamagnetism may exist without paramagnetism, paramagnetism is always accompanied by diamag-

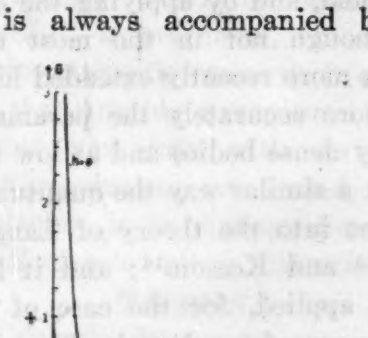

FIG. 7.

netism, as on all other theories. In weak fields and at low temperatures the paramagnetism may prevail; but as the temperature and field strength increase it goes over into diamagnetism.

A transition from paramagnetic to diamagnetic susceptibility, whatever may be the ex-

planation, has been observed by Weber and Overbeck[13] in the case of copper-zinc alloys, and by Honda in the case of indium. Weber and Overbeck, who have taken great precautions and believe their alloys free from iron, have called the phenomenon *metamagnetism.* The downward trend of paramagnetic susceptibility with increase of field strength is apparent in some of the curves obtained by Honda.

For weak fields at low temperatures, but with H/T finite, Gans's formula approaches that of Langevin as a limit. Here the paramagnetic rotations are prominent in comparison with diamagnetic thermal rotations about the other axes. As the field intensity approaches zero with finite values of the temperature the susceptibility approaches a limit which is the sum of two terms, a paramagnetic term identical with that of Langevin and a diamagnetic term independent of the temperature like that of Weber.

The theory of Gans thus covers a wide range of cases, but so far has been applied in detail to but few. By taking account of the molecular field, and by applying the quantum theory, although not in the most thorough way, he has more recently extended his theory to cover more accurately the paramagnetism exhibited by dense bodies and at low temperatures.[14] In a similar way the quantum theory has been set into the theory of Langevin by Oesterhuis[15] and Keesom[16]; and it has been thoroughly applied, for the case of rotation with one degree of freedom, by Weyssenhoff,[17] and for the case of rotation with two degrees of freedom by Reiche[18] and by Rotzajn,[19] to the system of elementary magnets, without permanent angular momentum, assumed by Langevin. These theories are thus not electron theories, like that of Gans. They reduce to the theory of Langevin at high temperatures when equipartition exists, and the rigorous theories agree well with experimental results obtained at low temperatures, where Langevin's theory completely fails. The next step should be the rigorous application of the quantum theory to the case in which the magneton has a permanent angular momentum, with gyroscopic properties, as required by the electron theory.

According to experiment hydrogen and helium are diamagnetic although according to Bohr's models their molecules have strong magnetic moments. This is apparently consistent with the theory of Gans, but inconsistent with the theory of Weber and Langevin. Honda and Okubo,[20] in a part of a paper dealing more generally with the kinetic theory of magnetism, have proposed the following explanation of this diamagnetic effect. Suppose the magnetic axis to be rotating about one of the other axes in a plane parallel to the magnetic intensity. On account of the presence of the field, the velocity of rotation, which would be uniform without the field, is now variable, the motion being more rapid when the moment points in the direction of the field than when it points the other way. Hence the time mean of its directions is opposite to that of the field and the mean effect is diamagnetic. If the magnetic axis is rotating in a plane not parallel to the direction of the field, we must resolve the effect in the direction of the field. Doing this for all the elementary magnets, originally pointing uniformly in all directions, we get a resultant diamagnetic effect. This, however, is only a part of the total effect found in Langevin's theory to be paramagnetic, though it is only implicit in his treatment, unless we assume *permanent* rotations, independent of the temperature, about an axis normal to the magnetic axis. This assumption they have made.

From what we have seen there seems to be no way to account satisfactorily for paramagnetism and ferromagnetism except on the assumption of an elementary magnet which is a permanent electrical whirl, as Ampère assumed; which has also mass, as Weber as-

[13] *Ann. der Phys.* (4), 46, 1915, p. 677.

[14] *Ann. der Phys.* (4), 50, 1916, p. 163.

[15] *Phys. Zeit.*, 14, 1913, p. 862

[16] *Phys. Zeit.*, 15, 1914, p. 8.

[17] *Ann. der Phys.* (4), 51, 1916, p. 285.

[18] *Ann. der Phys.* (4), 54, 1917, p. 401.

[19] *Ann. der Phys.* (4), 57, 1918, p. 81.

[20] *Phys. Rev.*, 13, 1919, p. 6.

sumed; and which has therefore the dynamical properties of a gyroscope. It will now be shown how these gyroscopic properties have made possible a complete and direct demonstration of the correctness of this theory.

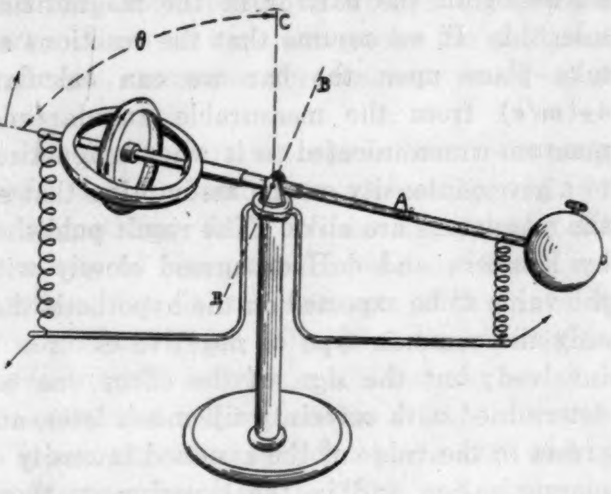

FIG. 8.

In Fig. 8 is shown a gyroscope whose wheel, pivoted in a frame, can be rotated rapidly about its axis A. Except for the action of two springs, the frame and the axis A are free to move in altitude about a horizontal axis B, making an angle θ with the vertical C; and the axis B and the whole instrument can be rotated about the vertical axis C. If the wheel is spun about the axis A, and the instrument then rotated about the vertical C, the wheel tips up or down so as to make the direction of its rotation coincide more nearly with the direction of the impressed rotation about the vertical axis C. If it were not for the springs, the wheel would tip until the axes A and C became coincident. The greater the rotary speed about the vertical the greater is the tip of the wheel. When the wheel's speed about the axis A is zero, no tip occurs.

Now if the magnetic molecule is a gyroscope, it will behave like this wheel. If the body of which it is a part is set into rotation about any axis, the molecule, or magneton, will change its orientation in such a way as to make its direction of rotation coincide more nearly with the direction of the impressed rotation; the coincidence will finally become exact if this is not prevented by the action of the rest of the body. This idea was in the mind of Maxwell in 1861, and has occurred to a number of others since.

In an ordinary ferromagnetic body in the usual state with which we are familiar only a slight change of orientation can occur on accunt of the forces due to adjacent molecules, which perform the function of the springs in the case of our gyroscope. The rotation causes each molecule to contribute a minute angular momentum, and thus also a minute magnetic moment, parallel to the axis of impressed rotation; and thus the body, whose magnetons originally pointed in all directions equally, becomes magnetized along the axis of impressed rotation. If the revolving electrons, or rotating magnetons, are all positive, the body will thus become magnetized in the direction in which it would be magnetized by an electric current flowing around it in the direction of the angular velocity imparted to it. If they are all negative, or if the action on the negative magnetons is preponderant, it will be magnetized in the opposite direction.

If R denotes the ratio of the angular momentum of a magneton, or an electron orbit, to its magnetic moment, it can readily be shown that rotating a magneton or electron orbit about any axis with an impressed velocity N revolutions per second, is equivalent to placing it in a magnetic field with intensity H directed along this axis such that

$$H = R2\pi N.$$

If the electric density is proportional to the mass density throughout the volume of the magneton this ratio is easily shown to be $R = 2m/e$; so that in this case

$$H = 4\pi \frac{m}{e} N. \qquad (16)$$

If all the magnetons in a body are alike, therefore, rotating it at an angular velocity of N r.p.s. will produce the same intensity of magnetization in it as placing it in a field of strength $4\pi(m/e)N$ gausses.

For negative electrons of the ordinary type $4\pi(m/e) = -7.1 \times 10^{-7}$ e.m.u. according to well-known experiments. Hence, if orbital motions of these electrons are responsible for the magnetism of ferromagnetic substances, rotating them at a velocity of N revolutions

per second should magnetize them as would a field of intensity

$$H = -7.1 \times 10^{-7} N \text{ gauss.} \tag{17}$$

Now in two investigations on cold-rolled steel by a method of electromagnetic induction, a third investigation principally on steel, nickel and cobalt by a magnetometer method, and a fourth investigation on steel, soft iron, cobalt, and Heusler alloy by another magnetometer method, Mrs. Barnett and I have found the above theory verified, except that in place of the number 7.1 we find smaller numbers; in the best work, which appears to be free from any serious systematic error, we find instead of 7.1 numbers about one half as great and even smaller.[21] This work, however, is still in progress.

If these results are correct, we seem to be driven to one of two conclusions: Either negative electrons or magnetons with a value of m/e or R for the motions involved different from that ordinarily accepted are responsible for magnetism; or positive electrons or magnetons, whose rotation we have seen must produce an opposite effect, are also involved. It does not seem impossible that a ring or other type of negative magneton, with R different for the permanent rotary motion from the value obtained from cathode ray experiments and otherwise, should be involved; but the presence of positive electron orbits, or rotating positive magnetons, is also possible, especially in view of the known expulsion of α particles with great velocities from the radioactive substances. Chemical evidence is often quoted in favor of the idea that superficial negative electrons alone are responsible for magnetism; but I do not think this evidence conclusive.

Not long after our first conclusive experiments on magnetization by rotation were communicated to this society, experiments on the converse effect, viz., rotation by magnetization, first suggested by Richardson, were performed by Einstein and deHaas.[22] Magnetizing a bar of iron, in turning the magnetons about until they all rotate in the same direction, produces angular momentum in this direction which must be compensated by an angular momentum within the molecules themselves, or in the bar, or in the magnetizing solenoid. If we assume that the reactions all take place upon the bar we can calculate $4\pi(m/e)$ from the measurable angular momentum communicated to it when magnetized to a given intensity on the assumption that all the magnetons are alike. The result published by Einstein and deHaas agreed closely with the value to be expected on the hypothesis that only the common type of negative electron is involved; but the sign of the effect was not determined with certainty till much later, and errors in the value of the assumed intensity of magnetization and in the experiments themselves undoubtedly exist. The experiments have been repeated with great improvements by Emil Beck,[23] and experiments on the same subject but by a different method had already been made by J. Q. Stewart;[24] both these investigations, on the basis of a single kind of electron and on the assumption made above with reference to the seat of the reaction to the electron momentum, give values of $4\pi(m/e)$ for iron and nickel similar to those which Mrs. Barnett and I have found by the method of magnetization by rotation, into the theory of which no assumptions appear to enter except such as can be justified completely.

If a magneton is sufficiently free it will, as stated above, when rotated about a given axis align itself with its axis completely parallel to the axis of impressed rotation. If in the unit volume there are N magnetons all alike, each with the moment of inertia C and initial angular velocity U about the magnetic axis, and if the effects of collisions and the demagnetizing field are negligible, the intensity of magnetization will be

$$I = \frac{NCe}{2m}(U + \Omega). \tag{18}$$

The first term is independent of Ω, which is a measure of the intrinsic intensity of rota-

[21] *Phys. Rev.*, 6, 1915, p. 239; 10, 1917, p. 7; *Proc. American Phys. Soc.* for December, 1920; *Proc. Phil. Soc. of Washington* for October 9, 1920.

[22] *Verh. d. D. Phys. Ges.*, 17, 1915, p. 152.

[23] *Ann. der Phys.* (4), 60, 1919, p. 109.

[24] *Phys. Rev.* (2), 11, 1918, p. 100.

tion, just as, in Voigt's equation, the first term is independent of H. The orientation is here produced by the rotation, but only the time taken to reach a steady state is affected by its magnitude. The second term, here added to the first, corresponds to Voigt's diamagnetic term. Here we have, except for the small second term, saturation for even very small values of Ω.

If collisions are not absent, or if the magnetic fields of adjacent molecules and the demagnetizing field become appreciable, the intensity of magnetization will not reach saturation; but it will increase with Ω, being greater for a given value of Ω the greater the mean interval between collisions, the less their violence, and the weaker the field.

It was suggested by Schuster in 1912 and by Einstein and deHaas in 1915, and earlier by myself, that the behavior of a magnetic molecule as a gyroscope might account for cosmical magnetism, as the direction of the magnetization of the earth and sun bear to the direction of the rotation the relation required by the theory. If the theory is quantitively sufficient, the interior of the earth and sun, as pointed out years ago, must be in a very different state from that of bodies with which we are familiar. If m/e reaches enormous values for magnetons within the earth and sun, which is not probable, or if the magneton density is sufficiently high and the effects of collisions and the molecular and demagnetizing fields at the same time sufficiently small, it is possible that even the small angular velocities of the earth and sun may be sufficient to produce the observed magnetizations.[25]

S. J. BARNETT

DEPARTMENT OF TERRESTRIAL MAGNETISM,
CARNEGIE INSTITUTION

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

SPRING MEETING OF THE EXECUTIVE COMMITTEE

THE executive committee of the council of the association held its regular spring meeting in the Cosmos Club, Washington, D. C., on the afternoon and evening of Sunday, April 24. The following paragraphs summarize items of business that were transacted. The personnel of the executive committee is as follows:

Simon Flexner (chairman), J. McK. Cattell, H. L. Fairchild, L. O. Howard, W. J. Humphreys, B. E. Livingston (permanent secretary of the association), D. T. MacDougal (general secretary of the association), E. H. Moore (president of the association), A. A. Noyes, Herbert Osborn, H. B. Ward. All of the members were present at this meeting, excepting Messrs. Flexner, Moore, and Noyes. The meeting was called at 4.00 P.M.

After the minutes of the last meeting of this committee (Chicago, Dec. 29, 1920) had been read and approved it was voted that the next meeting of the executive committee "shall occur in New York City on the first Sunday after November 1 that shall be convenient to a majority of the members," the exact date to be arranged by the permanent secretary.

It was voted that the action thus far taken by the American Association committee on conservation, be approved and that that committee be authorized to proceed with its plans. (The committee on conservation consists of J. C. Merriam (chairman), H. S. Graves, Barrington Moore, V. E. Shelford and Isaiah Bowman. It held a meeting in New York City on April 9, jointly with corresponding committees of the National Academy of Sciences and the National Research Council, and it was recommended that these three committees form a continuing joint committee on national conservation, representing the three organizations just mentioned, and that this joint committee be authorized to set up an executive and secretarial agency for the active prosecution of its work.)

The executive committee ratified the action taken by the committee on honorary life memberships through the Jane M. Smith fund, in placing the names of the distinguished scientists, J. E. Clark and J. N. Stockwell, recently deceased, on the list of honorary life members of the Association. (Both were ac-

[25] See papers by Professor S. Chapman and by myself in *Nature*, Nov. 25, 1920, and March 3, 1921.

tive members of the Association from 1875 until death.)

Dr. J. C. Fields, president of the Royal Canadian Institute, was elected chairman of the local committee of the American Association, for the forthcoming Toronto meeting.

Dr. Sam F. Trelease (assistant secretary of the association) was elected secretary of the council for the Toronto meeting.

It was voted that a special committee consisting of the president, the permanent secretary, and the general secretary should arrange, in cooperation with the local committee for the Toronto meeting, for the invitation of an eminent British man of science to attend the Toronto meeting, to give a general public lecture on the evening of Friday, December 30, and to present such scientific papers as he may be willing to give, before the section of the association or the affiliated societies to which his field of science may be related.

It was voted that the British Association for the Advancement of Science be invited to be officially represented at the Toronto meeting. A committee consisting of the president and the two secretaries was authorized to invite representation by other organizations at the Toronto meeting. Dr. J. McK. Cattell was elected to be an official delegate of the American Association to attend the forthcoming Edinborough meeting of the British Association. The committee mentioned was authorized to appoint other representatives.

It was voted that the permanent secretary and the general secretary be constituted a special committee to render a decision in the case of any fellowship nomination for which the section secretary may fail to make definite recommendation. (Nominations for fellowship in the Association may be made by any member in good standing, including the nominee himself, and they are immediately referred, by the permanent secretary, to the proper section secretary, who investigates each nomination and transmits it, with his recommendation to the permanent secretary for reference to the executive committee. The executive committee acts for the council in electing fellows at the spring and autumn meetings of the committee and it recommends fellowship elections to the council when a council session follows promptly upon the committee meeting—as during the annual meetings of the association. Only fellows may hold office in the association and fellows are designated by an asterisk in the list of members.)

The American Society for Testing Materials (C. L. Warwick, secretary, 1315 Spruce Street, Philadelphia, Pa.) was constituted an affiliated society. (The membership of the society includes 62 fellows of the association and the society is therefore entitled to one representative in the association council.)

The American Society of Agronomy (P. E. Brown, secretary, Iowa State College, Ames, Iowa) was constituted an affiliated society. (The membership of the society includes 93 fellows of the association and the society is therefore entitled to one representative in the association council.)

The American Geographical Society of New York (Isaiah Bowman, director, Broadway at 156th Street, New York City) was constituted an affiliated society.

The North Carolina Academy of Science (Z. P. Metcalf, president, North Carolina Experiment Station, West Raleigh, N. C.) was constituted an affiliated academy, according to the special arrangement for the affiliation of academies. (Affiliated academies collect the association dues of those of their members who are also members of the association. They each have a representative in the association council and they are allowed to retain the entrance fees collected and one dollar of each annual dues collected. When an academy is first affiliated it receives from the association one dollar for each one of its members that have already paid to the permanent secretary association dues for the current year.)

The Maryland Academy of Sciences was constituted an affiliated academy, according to the special arrangement just mentioned.

Professor T. W. Todd, professor of anatomy, Western Reserve University, Cleveland, Ohio, was elected a member of the section committee

of Section H (Anthropology), to take the place of Dr. Berthold Laufer, resigned from the association. (The new committee member's term of office expires at the end of the 1924–25 annual meeting.)

A special committee, consisting of J. McK. Cattell (chairman), L. O. Howard, D. T. MacDougal, and B. E. Livingston, was appointed to arrange for sections C, K, L, M, and N at the Toronto meeting, this committee to cooperate with the corresponding section committees in so far as their members have been elected. It was voted that this committee should organize a committee of seven members for each of the three fields, (*a*) Social and Economic Sciences, (*b*) Engineering, and (*c*) Medical Sciences, each of these three committees to survey the general relations between the association and the committee's province, with the aim of securing more satisfactory representation of that field of science in the work of the association. It was recommended that the membership of these three committees include eminent scientists without regard to their membership in the association, the permanent secretary and at least one other member of the association being on each.

The question regarding the organization of the History of Science was again given careful consideration by the executive committee. The special committee that arranged the excellent program on this subject for the Chicago meeting has expressed itself as in favor of the History of Science being made the field of a new section of the association, but the consideration that this field overlaps the fields of the already existing sections has prevented the executive committee from concurring with the special committee on this point. The council of the association (at its Chicago meeting) favored the organization of the History of Science as a part of Section L (Historical and Philological Sciences), not yet organized, but the special committee does not favor this arrangement. The executive committee finally concluded to suggest that a special society for the History of Science might be inaugurated and that this society might become an affiliated society of the association.

At the suggestion of the American Society of Zoologists, a resolution was adopted favoring the duty-free importation of scientific materials into the United States by educational and research institutions.

The executive committee expressed its regret that, owing to lack of funds, the association found it impossible to comply with a suggestion recently received from the Hall of Fame of New York University, that the association provide a bust of an eminent scientist for the Hall of Fame. Upon invitation from the chancellor, the council and the committee on the Hall of Fame of New York University, three delegates were appointed to represent the Association on the occasion of the unveiling of a tablet in honor of Louis Agassiz—a past president of the Association—this ceremony to occur in the colonnade of the Hall of Fame, at University Heights, New York City, on May 21, 1921. Messrs. C. B. Davenport, H. F. Osborn, and E. B. Wilson were appointed.

A proposal to establish a section on the Evolution of Religion and Philosophy was given consideration and it was voted that, "since the subjects referred to are already provided for by existing sections of the Association, it seems unnecessary to inaugurate a special section for them at this time."

Four new items were approved for the permanent secreary's budget for 1921, these having been omitted from the budget as approved by the council at the Chicago meeting. A statement of the entire budget follows:

Permanent Secretary's Budget for 1921.

Items approved by the Council at the Chicago Meeting:

Journals	$36,000.00
Salaries:	
Permanent secretary	2,500.00
Executive assistant	2,520.00
Usual clerical help	2,000.00
Special clerical help for new membership list	800.00
Travel expenses, section secretaries, etc.	1,500.00
Office supplies	800.00
Stationery and printing	2,400.00

Telephone, etc.	100.00
Postage	800.00
Expenses of Chicago meeting	1,000.00
Membership list, printing (balance not provided by sale of list)	1,000.00
Miscellaneous	500.00
Benjamin collection of portraits and autographs of Association presidents	300.00
Total approved at Chicago	$52,220.00

Additional items approved by Executive Committee April 24, 1921:

Dollar payments to divisions and dollar allowances to affiliated academies (according to rules of procedure)	$ 2,400.00
Printing and mailing (to all members) the Preliminary Announcement of Chicago meeting	955.36
Grant for research (arranged for by Committee on Grants but not covered by appropriable funds in the treasurer's hands at end of 1920; approved by Executive Committee, March 7, 1921)	500.00
Salary, assistant secretary (authorized by Council at Chicago meeting)	1,000.00
Total, additional items	$ 4,855.36
Total of modified budget	$57,075.36

The executive committee expressed itself as interested in the work for the advancement of science accomplished through the grants thus far made for research and the permanent secretary was instructed to communicate with the committee on grants and to arrange with that committee for the preparation of a general report on grants for research made by the Association from year to year.

The permanent secretary presented a report on the affairs of the Association, a summary of which will appear in a later issue of SCIENCE.

The general secretary presented a report considering the following items: (*a*) The supplying of the past publications of the Association to scientific institutions outside of the United States. (*b*) The committee on Mexican scientific organization (see SCIENCE, N. S., 53: 4, 1921) is active and the work is in progress. (*c*) The general secretary is making a study of the problem of securing a fuller attendance of members of the council at council meetings.

A campaign for new members, especially among residents of Canada, was authorized, with special reference to preparations for the Toronto meeting. It was recommended that the medical men of the United States be specially invited to join the association.

It was voted that the edition of the new volume of the Summarized Proceedings of the association should include (*a*) the number of copies ordered and paid for in advance at the time of printing (over 1,600 copies were thus accounted for on April 23) and (*b*) an extra supply of 500 copies. The permanent secretary was authorized to distribute not over 50 copies gratis, to a selected list of libraries, etc., throughout the world. (The volume, including the Membership List, will appear about June 1. It may be purchased by members of the association for $1.50 if payment be made in advance of the final going to press; the price to non-members is $2.00.) It was voted that the price of the 1921 volume of Summarized Proceedings, including the Membership List, should be $2.00 to members and $2.50 to non-members, after the date of publication.

It was voted that the association would welcome an address, at the Toronto meeting, under the auspices of the Society of Sigma Xi, an affiliated society of the Association.

The committee adjourned at 10.05, to meet in New York City early in November.

BURTON E. LIVINGSTON,
Permanent Secretary.

MEDALS OF THE NATIONAL ACADEMY OF SCIENCES

AT the annual dinner of the Academy held at the Hotel Powhatan on April 26, a surprise was sprung upon the president, Dr. Charles D. Walcott, when Dr. W. H. Welch took the chair and introduced Dr. J. M. Clarke of the State Museum, Albany, New York, who out-

lined the scientific career of Dr. Walcott and announced that the committee had selected him as the first recipient of the Mary Clark Thompson Gold Medal for "eminence in geology and paleontology." Dr. Walcott in responding told how his attention had been attracted as a boy to the trilobites in the rocks near the old swimming hole and how he had pursued the study of these fossils with peculiar interest to the present day, for his paper read before the academy in its session that afternoon dealt with the structure of these trilobites.

In awarding the Agassiz medal President Walcott told of the desire expressed by Sir John Murray, on his visit to this country, to leave a fund to commemorate Alexander Agassiz, which took the form of the Agassiz Gold Medal for "original contributions to the science of oceanography." The medal for 1918 was awarded to His Serene Highness, Albert I., Prince of Monaco, the guest of the evening.

Dr. W. H. Dall of the Smithsonian Institution, described the scientific researches of the Prince of Monaco in the investigation of ocean currents and ocean life, including voyages in his especially equipped yachts from the Azores to the Arctic. The Prince founded at Monaco the Museum of Oceanography; later at Paris the Institute of Oceanography, and last December opened at Paris the Institute for Human Paleontology.

The Prince in reply said he had never expected that the work he had done with such pleasure would lead to the great honor he had now received. This honor, he said, should be shared with the companions who have worked for thirty-five years with him on board ship and in the laboratories. The Prince expressed the high regard which he has always held for the American people and for the political conditions which gave an opportunity for the reward of honest labor not to be matched elsewhere in the world.

President Walcott next announced the award of the Henry Draper medal to Dr. P. Zeeman of Amsterdam, Holland. Dr. C. G. Abbot read a letter from Dr. William W. Campbell, of the Lick Observatory, explaining the importance of the work of Zeeman in demonstrating the doubling and tripling of the lines of the spectrum in a magnetic field twenty-five years ago. Dr. Abbot pointed out that by the study of the Zeeman effect Dr. George E. Hale, of the Mount Wilson Observatory, had been enabled to map the magnetic field of the sun spots and to show that the sun itself is a magnet. This led to the discoveries in spectroscopy announced by Dr. Hale at the present session of the Academy.

In the absence of Professor Zeeman the medal was received in his behalf by the Secretary of the Legation of the Netherlands.

Dr. Henry Fairfield Osborn of the American Museum of Natural History, New York, gave a sketch of the life and work of Dr. Robert Ridgway to whom was awarded the Daniel Giraud Elliot Gold Medal for his studies in American Ornithology. Dr. Ridgway was born in Cromwell, Illinois, and at the age of fourteen discovered his first new bird. This brought him to the attention of Professor Baird. At seventeen he became a member of the Clarence King Survey of the west. Ridgway's "Birds of Northern and Middle America" is the most exhaustive and complete treatise on birds of any region in the world. A letter was read from Dr. Ridgway in which he paid high tribute to Daniel Giraud Elliot as his inspiration and example.

The Alexander Agassiz gold medal for 1920 was awarded to Rear Admiral C. G. Sigsbee, U.S.N., retired, who was assigned to hydrographic work in 1874 and carried out on the *Blake* a remarkable series of explorations in the Gulf of Mexico on new methods of deep sea sounding and temperature reading. Admiral Sigsbee not being present, the medal was received in his behalf by Rear Admiral Taylor, who read a letter from Admiral Sigsbee telling of the time when Professor Agassiz was on board the *Blake*.

The gold medal for eminence in the application of science to the public welfare was awarded to Dr. C. W. Stiles. Dr. Welch sketched the life of Dr. Stiles and described his achievements in the field of medical zool-

ogy. His greatest achievement was in recognizing the importance of the hookworm disease and in carrying out with the aid of the Rockefeller fund wholesale measures for its suppression. Dr. Stiles discovered the American variety of hookworm and made a complete survey of the south. At a result of this work the most severe cases of the disease have been eliminated from this country.

Dr. Stiles in receiving the medal told of the contempt that in his early days was cast upon those who attempted to make utilitarian applications of a science like zoology. But in spite of this attitude of hostility toward applied zoology he decided in 1891 to enter the field. Since then zoology has been of service to public health in many ways and there are great opportunities for the future. For instance typhoid fever is now so well understood that it could be completely eradicated by sufficient effort. Dr. Stiles stated he received the medal not so much as an individual but rather as a representative of the Public Health Service.

Dr. Albert Einstein of Berlin was called upon at the close of the session and replied very briefly in German, saying that he would not then speak, but would try to learn English before his next visit to Washington.

E. E. Slosson

Science Service

THIRD AWARD OF THE DANIEL GIRAUD ELLIOT MEDAL

The third award of the Daniel Giraud Elliot gold medal, namely, for the year 1919, together with the honorarium, was voted to Robert Ridgway in recognition of the eighth volume of "The Birds of Middle and North America," which appeared in the year 1919. The two previous awards of this medal were to Frank M. Chapman for his "Distribution of Bird-Life in Colombia," which appeared in 1917, and to William Beebe for the first volume of his "Monograph of the Pheasants," which appeared in 1918. Thus for the third time an American ornithologist secures this medal, an award which is open to the zoologists and palæontologists of the world.

In his address as chairman of the Elliot Medal Committee Professor Osborn spoke as follows:

In undertaking this great work Ridgway was not only placing the crown on his labors of a third of a century, but was giving expression to a plan made by Baird a half century before. Ridgway was therefore doubly inspired when, in 1901, he undertook the stupendous task of preparing a ten-volume treatise on all the birds of the western hemisphere north of South America. With unremitting zeal, and always maintaining the standard of thoroughness and accuracy set by the first volume of the series, he continued his labors until eight volumes have appeared, the last in 1919. Each volume contains about 850 pages, or a total of 6,800 pages in all. Nearly 900 genera are defined and over 3,000 species and subspecies described.

While giving expression to his exceptional powers of analysis and description trained by years of experience and observation, Ridgway has produced a work which in method, comprehensiveness, and accuracy, as well as in volume, has never been surpassed in the annals of ornithology.

It is interesting to add that, like the poet, the ornithologist is born, not made. Remote from museums, libraries, and naturalists, Robert Ridgway was born at Mt. Carmel, Illinois, July 2, 1850. At the age of fourteen we find him trying to identify local birds with the aid of Goldsmith's "Animated Nature" and Goodrich's "Natural History." His first touch with Washington as the great center of ornithological research came through a letter enclosing a colored drawing of the Purple Finch, to which the young ornithologist gave the name "Roseate Grosbeak" (*Loxia rosea*). This letter found its way to the sympathetic hands of Assistant Secretary Spencer F. Baird of the Smithsonian Institution. In Baird Ridgway found a preceptor and friend eminently qualified to guide his special talents. Baird found in Ridgway a pupil who in due time became his worthy successor; and cordial relations then established have continued to bear fruit during the succeeding fifty-seven years.

At the early age of seventeen, that is, in 1867, Ridgway was appointed zoologist of the United States Geological Survey of the 40th Parallel, under Clarence King. Remaining in the employ of the government, he became, in 1880, curator of the Division of Birds in the United States National Museum, a position he still occupies. He was a founder of the American Ornithologists' Union and from 1898 served as its president. A retiring

disposition and close application to his studies have prevented him from taking a prominent part in the activities of natural history organizations, and thereby he has gained time for research which has placed to his credit a greater number of works than has been produced by any other ornithologist. With Baird and Brewer he collaborated in the production of a five-volume quarto on the "Birds of North America." This was followed by his standard "Manual of North American Birds," "Nomenclature of Colors for Naturalists," "Birds of Illinois," and "Color Standards and Color Nomenclature," a work generally accepted by naturalists throughout the world. Meanwhile he had published also some five hundred papers of varying length, and it was not until 1901 that the way was prepared for his *magnum opus*, "The Birds of Middle and North America," the eighth volume of which has won for him the award of the Daniel Giraud Elliot Medal by the National Academy of Sciences.

According to the deed of gift, the award of the Elliot Medal is made "to the author of such paper, essay or other work upon some branch of zoology or palæontology published during the year as in the opinion of the persons, or a majority of the persons, hereinafter appointed to be the judges in that regard, shall be the most meritorious and worthy of honor. . . . As science is not national the medal and diploma and surplus income may be conferred upon naturalists of any country, and as men eminent in their respective lines of scientific research will act as judges, . . . no person acting as such judge shall be deemed on that account ineligible to receive this annual gift, and the medal, diploma and surplus income may in any year be awarded to any one of the judges, if, in the opinion of his associates, he shall, by reason of the excellence of any treatise published by him during the year, be entitled to receive them." Nominations on the work of the year 1920 in zoology and palæontology should be addressed to the Home Secretary of the National Academy of Sciences, Smithsonian Institution, Washington, D. C., by whom they will be forwarded to the committee on award.

HENRY FAIRFIELD OSBORN

AMERICAN MUSEUM OF NATURAL HISTORY,
NEW YORK CITY, May 4, 1921

SCIENTIFIC EVENTS

THE UNITED STATES PATENT OFFICE

THE United Engineering Societies have issued a statement in regard to the situation in the United States Patent Office, calling attention to the fact that wholesale resignations are crippling the service to the point of disorganization and are creating conditions that threaten American industrial enterprise and invention. The council, through its Patents Committee, of which Edwin J. Prindle, of New York City, is chairman, reports that the situation has become almost intolerable and quotes the new commissioner of patents, Thomas E. Robertson, as saying that remedial legislation at the present session of Congress is necessary if results approaching disruption are to be prevented.

The council appeals for support of pending patent legislation, which provides sufficient increases in salaries to check the exodus of employees from the Patent Office to private employment. In a little over one year, 110 members of the force of examiners, numbering 437, have resigned. During the first three weeks of the Harding administration six highly trained experts left the service to accept salaries two or three times as great elsewhere. In the past year 142 of the 560 clerical workers have resigned. There are thirty clerks in the Patent office who receive only $60 a month who would get $1,100 a year under the new salary bill.

Commissioner Robertson is quoted as stating that the Patent Office runs one of the largest ten-cent stores in the world. The enterprise has as its stock about 75,000,000 copies of about 1,500,000 patents, and new patents at the rate of from 600 to 1,000 a week add 50,000 more copies to be taken care of each week. Many patent copies are sold for a dime apiece during the year. There is a stenographic department handling legal work that turned out 13,000,000 words in the past year and brought in $62,000 revenue.

It is the opinion of the engineering, research and manufacturing associations of the United States that the scientific and industrial interests of the country are being jeopardized by

Patent Office conditions. The National Research Council, the American Chemical Society and the National Association of Manufacturers are among the organizations advocating Patent Office relief.

THE NATIONAL GEOGRAPHIC SOCIETY

Because of their important service "for the increase and diffusion of geographic knowledge" the following members of the National Geographic Society have been awarded life memberships, under the provisions of the Jane M. Smith Fund:

R. G. McConnell, of Ottawa, Canada, for his distinguished service to geography in Canadian exploration.

Frank M. Chapman, of New York City, for his researches in ornithology with special reference to the geographic distribution of animal life.

Herbert E. Gregory, of New Haven, Connecticut, for his important original contributions to geographic science.

Donald B. MacMillan, of Freeport, Maine, for his additions to geographic knowledge through Arctic exploration.

J. B. Tyrrell, of Toronto, Canada, for his journeys and reports of exploration and discovery in the wilderness of northwestern Canada.

The National Geographic Society will begin explorations and studies this summer of the Pueblo Bonito and Pueblo del Arroyo ruins in the Chaco Canyon of Northwestern New Mexico. It was decided to study these ruins following a report to Dr. Gilbert Grosvenor, president of the society, and its research committee, headed by Frederick V. Coville, by a reconoissance party which visited the Canyon last summer (1920). The expedition will be led by Neil M. Judd, who has been a member of many expeditions to the American Southwest. The populous habitation of the Canyon in pre-Columbian times presents numerous geographical problems involving the relation of a specialized environment to a people whose traces indicate numerous special characteristics. Not only will the architecture and ceramic remains be studied, but experts in desert flora and geology will accompany the expedition. It is yet to be determined whether the climate conditions have changed or whether the canyon agriculturists had an irrigation system for their crops of beans, corn and squash.

EXCHANGE OF PROFESSORS OF ENGINEERING BETWEEN AMERICAN AND FRENCH UNIVERSITIES

There has been for some time a regular annual exchange of professors between individual universities in France and America in regular academic fields, such as literature, history, law, fine arts, economics, etc., but no such exchange in engineering or applied science. These subjects are taught in France under special faculties, not included in existing exchanges with America. Furthermore, the French methods of teaching these subjects are unlike our American methods, for various reasons, based on the history, traditions and sociology of the two countries. The war showed the importance of engineering in production and distribution, and the many ties of friendship which bind us to France depend in various ways, upon applied science. It should therefore, be to the mutual advantage of France and America to become better acquainted with each other's ideals and viewpoints, in the study and in the teaching of these subjects.

With these purposes in mind, the late Dr. R. C. Maclaurin, in 1919, as president of the Massachusetts Institute of Technology, consulted the presidents of six universities on or near the Atlantic seaboard, as to whether they deemed it desirable to cooperate in a joint exchange of professors with France, on a plan definitely outlined. Their replies being favorable to the project, a committee was appointed, with one member from each of the seven institutions, to report on the plan, and on methods of carrying it into effect. The committee met in December, 1919, and ratified the cooperative plan with some few modifications. The present president of the committee is Director Russell H. Chittenden, of Yale University, and its secretary Dean J. B. Whitehead of the Johns Hopkins University.

Since the Institute of International Education, in New York, concerns itself with the interchange of college students and teachers

from all parts of the world, the committee requested the director, Dr. Stephen P. Duggan, to undertake the negotiations between the committee and the French university administration. The French administration responded cordially to the offer for the annual exchange of a professor. The French have selected, for their first representative, Professor J. Cavalier, rector of the University of Toulouse, a well-known authority on metallurgical chemistry, to come to America this fall, and to divide his time during the ensuing academic year, among the seven cooperating institutions, namely, Columbia, Cornell, Harvard, Johns Hopkins, the Massachusetts Institute of Technology, Pennsylvania and Yale.

The American universities have selected as their outgoing representative for the same first year (1921–22), Dr. A. E. Kennelly, professor of electrical engineering at Harvard University and the Massachusetts Institute of Technology.

GRANTS FROM THE BACHE FUND

GRANTS from the Bache Fund of the National Academy of Sciences have been made as follows:

$500 to C. H. Warren, Massachusetts Institute of Technology, to defray the expense of chemical analysis in the study of igneous rocks from Massachusetts.

$500 to Waldemar Lindgren, Massachusetts Institute of Technology, for chemical analyses of samples used in a study of additions and losses that limestones from Bingham, Utah, have suffered in contact metamorphism.

$500 to T. H. Goodspeed, University of California, for photographic records and illustration, over a period of three years, for a study of *Nicotiana* in respect of Mendelian inheritance, of quantitative inheritance, of inheritance of inter-specific hybrids, and of the nature of bud variation.

$1,000 to Frank P. Underhill and Lafayette B. Mendel, Yale University, for investigations on deficiencies in nutrition.

$500 to Gilbert N. Lewis, University of California, for the computation of chemical constants.

$300 to H. W. Norris, Grinnell College, Iowa, for the investigation of the nervous system of the Elasmobranch fishes, and for the study of the Ganoid fishes.

$750 to Preston Edwards, Johns Hopkins University, for investigations in acoustics.

SCIENTIFIC NOTES AND NEWS

MME. CURIE, accompanied by her two daughters, arrived in New York City on May 11. Last week she visited Smith, Mt. Holyoke and Vassar Colleges. According to the program that has been arranged, she is given this week a luncheon by the chemists of New York City, a welcome by the American Association of University Women, and a reception at the American Museum of Natural History. On Friday President Harding presents her with a gram of radium on behalf of the women of America.

DEAN ALBERT R. MANN, of the New York State Agricultural College at Cornell University, has been appointed head of the New York State Agricultural Department by the reorganized Council of Farms and Markets. There were three candidates—Raymond R. Pearson and George E. Hogue, who have each held the office, and Dean Mann.

DR. R. W. THATCHER, dean of the department of agriculture and director of the agricultural experiment station of the University of Minnesota for the past four years, has resigned in order to accept the appointment as director of the New York State Agricultural Experiment Station at Geneva, N. Y., effective on July 1. Dr. W. H. Jordan, who completes twenty-five years of service as director of the station at Geneva on June 30, retires on that date.

DR. W. J. MAYO and Dr. C. H. Mayo have recently received notification that honorary fellowships in the Royal College of Surgeons of Ireland will be conferred upon them as soon as they can attend the ceremony which will be held in the College Hall.

DR. THEODORE HOUGH, dean of the medical

department of the University of Virginia, has been elected president of the Association of American Medical Colleges.

Dr. Harry P. Brown, of the New York State College of Forestry, has declined the position of wood technologist at the Imperial Forest Research Institute, Dehra Dun, United Provinces, India, offered to him by the Secretary of State for India.

Sir Wilmot Herringham, chairman of the Committee on Medical Education of the University Grants Committee, and Sir Walter Morley Fletcher, secretary of the Medical Research Council of London, guests of the Rockefeller Foundation, visited the Mayo Foundation and the Mayo Clinic on April 26 and 27.

Arnold William Reinold, F.R.S., for thirty-five years professor of physics at the Royal Naval College, Greenwich, died on June 19, aged seventy-eight years.

Dr. James Law, director emeritus of the New York State Veterinary College, Cornell University, died in Springfield, Mass., on May 11, aged eighty-three years.

Dr. Michael Idvorsky Pupin, professor of electro-mechanics at Columbia University, addressed the meeting of the Columbia Chapter of Sigma Xi on May 4. He spoke on "Progress in physics in the last decade." This was the first of a series of annual lectures on "The Progress of Science."

Dr. T. Wingate Todd, Payne professor of anatomy in the Medical School of Western Reserve University, will deliver in June five special lectures at the University of Ghent, Belgium, on "The growth and metamorphosis of the skeleton." The lectures are supported by the Hoover Foundation provided by the funds remaining after the Commission for the Relief of Belgium had finished its activities.

Professor Albert Einstein, who delivered a series of five lectures on the theory of relativity at Princeton University during the week beginning on May 9, has arranged with the Princeton University Press for their publication in book form. This will be the only authorized publication of the lectures he will give during his present visit to the United States.

The last issue of the *Journal* of the Elisha Mitchell Scientific Society carries an appreciation of the work of Dr. J. J. Wolfe (Harvard), late professor of biology of Trinity College, Durham, N. C. The Biological Club of this institution is raising funds and collecting books for a memorial library.

UNIVERSITY AND EDUCATIONAL NEWS

The West Virginia legislature has appropriated for the University of West Virginia $400,000 for a chemistry building; $300,000 for a gymnasium and $100,000 to complete the law building.

The will of Mrs. William L. McLean, wife of the publisher of the Philadelphia *Evening Bulletin*, leaves $100,000 to Princeton University in memory of her son Warden McLean, of the class of 1912, who was killed in the war.

The inauguration of Dr. Ernest Fox Nichols as president of the Massachusetts Institute of Technology will take place on June 8. Addresses will be made by Governor Cox, Dr. Elihu Thomson, President A. Lawrence Lowell and Professor H. P. Talbot, followed by the inaugural address of Dr. Nichols.

Dr. John Howland, professor of pediatrics at the Johns Hopkins Medical School, director of the Harriet Lane Home and pediatrician in chief of the Johns Hopkins Hospital, has been offered the professorship of children's diseases in the Medical School of Harvard University.

DISCUSSION AND CORRESPONDENCE

EFFECT OF DORMANT LIME SULFUR UPON THE CONTROL OF APPLE BLOTCH

During the progress of investigations on apple blotch (*Phyllosticta solitaria* E. & E.) new and noteworthy facts concerning this important disease are gradually coming to light.

Of particular concern, from the practical viewpoint, is the effect of dormant lime sulfur and copper sulphate sprays upon the pycnospores lodged in the pycnidia and destined to function after petal-fall.

Wallace[1] in his official reports and Douglas[2] have repeatedly published the statement that a very strong solution of lime sulfur, applied before the buds begin to swell, perfectly controlled this disease and that the summer sprays, consequently, were unnecessary. The writer disagrees with their views, but has discovered from field and laboratory experiments and obervations, the scientific explanation of partial control by the dormant sprays applied late.

The infectious surface of an apple blotch canker in the first season of its functional activity consists of two distinct portions: first, that portion which develops from a single infection, becoming apparent in late summer and ceasing its active growth upon the appearance of cold weather; second, that porton which advances from the initial canker the following spring, approximately two weeks after the buds burst open, and which becomes dotted with pycnidia, with mature pycnospores, simultaneously with the advance of the canker. The first portion is the initial canker and bears pseudo-pycnidia. The contents of the pseudo-pycnidia are completely or partially differentiated into spores by the time it is customary to apply the dormant spray. Furthermore, the epidermal covering over the pycnidia is ruptured, exposing the pycnidial wall. The season's young fruits and new growth are, therefore, subject to two distinct sources of infection from the young blotch cankers.

A dormant spray of lime sulfur applied as the buds begin to swell actually kills the spores and sporidal layer within the differentiated pseudo-pycnidia but has absolutely no effect upon the mycelium of the organism ramifying throughout the cortical tissue beneath. The toxic effect upon the spores is very striking after the first rain following the dormant spray. Dilutions of lime sulfur of 1-3, 1-5, 1-6, and 1-8, were given their trial and all were similarly toxic to the spores in the pycnidia, but it appeared that dilutions somewhat stronger than 1-8 were more efficient. A dilution of copper sulphate (1-6) produces similar toxic effects. Scalecide produces none at all.

As was mentioned above, a new infectious area advances from the initial canker in the spring. It follows, therefore, that the dormant spray exercises but very little control upon the season's infection of the young apples and new growth.

E. F. GUBA

UNIVERSITY OF ILLINOIS

[1] Wallace, F. N., 9th Annual Report Indiana State Entomologist, 1915-16, pp. 51, 54.

[2] Douglas, B. W., "War and the Fruit Grower," *Country Gentleman*, September 14, 1918; "Fruit Diseases of 1919," *Country Gentleman*, April 17, 1920.

CROWS AND STARLINGS

TO THE EDITOR OF SCIENCE: Last fall at Devon, Pennsylvania, a man shooting blackbirds also wounded a starling, which fell on the grass and which he could not find. Shortly afterwards several crows were seen diving at something in the grass and then lighting and running through the grass after it. Upon his going towards them to see what they were doing, they all flew away, one of them carrying the starling in its bill, and landed on the walk in a neighboring place, where the crows gathered round the starling and proceeded to peck at it. He followed them and scared them, and the crows flew away, abandoning the starling, which was nearly dead.

I have never before known of crows carrying off as large a bird as a starling, though I have seen one carrying off from the nest a young robin nearly ready to fly, and of course they kill many young robins and other young birds of smaller size.

F. R. WELSH

THE SYNCHRONAL FLASHING OF FIREFLIES

DURING a trip in Siam, a distinct flashing of fireflies in unison was observed. The observa-

tions were made during the evenings of June 5 and 6, 1920, from a house boat on the Tachin River, in the district of Sarm Prarm, Nakorn Chaisri, Siam. A distinct flashing of dark and light was observed. A whole tree of flies would flash all together at regular intervals of, by count with a watch, between 105 and 109 flashes a minute.

Frequently entire trees filled with fireflies are observed at the College of Agriculture, Los Baños, Laguna, Philippine Islands and it was at first thought by the writer that an extremely rapid flashing in unison took place. After, however, observing the distinct flashing in unison of the fireflies in Siam it can be stated with certainty that no such synchronal flashing took place at Los Baños.

Determinations made by H. E. Woodworth, of the College of Agriculture, Los Baños, on fireflies from Siam, showed these flies to be of the genus *Calaphotia*. Professor Woodworth states that the firefly at Los Baños is of the same genus, but of a different species. Neither species has been determined.

OTTO A. REINKING

COLLEGE OF AGRICULTURE,
LOS BAÑOS, PHILIPPINE ISLANDS

FRANZ STEINDACHNER

TO THE EDITOR OF SCIENCE: I read with much interest the article of Dr. Jordan on Franz Steindachner. I had the great pleasure of visiting Dr. Steindachner twice; once in 1878 and again twenty years later in 1898. He was living in the simple way described by Dr. Jordan on the occasion of both my visits. His maiden sister at that time, however, was living and was keeping house for him in a perfectly simple manner.

I do not wish to speak of Steindachner's great achievements in ichthyology. I want to add my little tribute to his value as a friend. The simplicity of his life, the wonderful clarity of his character and his devotion to his friends make him almost as renowned as his achievements in the investigation of fishes. At the time of my last visit he had achieved the full distinction of head superintendent of the Royal Imperial Museums. He enjoyed to a remarkable degree the confidence of the Emperor Franz Josef. Through a special permit from the imperial palace I was permitted under his guidance to visit the castle with all of its belongings in which the heir to the throne was murdered a few years before.

I was particularly struck with the amity and friendship shown him by the people with whom he worked. As a host he was the essence of geniality and at the same time of simplicity. I carried letters to him on my first visit from friends in Harvard who knew him when he was a resident of Cambridge. He had a great admiration for this country and he numbered many personal and professional friends on this side of the water. While war broke up all political and many social relations with Germany and Austria, I feel quite certain all the personal friends of Dr. Steindachner on this side remained loyal to him through his later years of sorrow and distress, due to the exigencies of the war. The grief for him as a friend is more poignant than the regret of his loss to science.

H. W. WILEY.

SCIENTIFIC BOOKS

Chemische Krystallographie. By P. GROTH. Leipzig, Wilhelm Engelmann. Vol. I., 1906; II., 1908; III., 1911; IV., 1917; V., 1919. 4,443 pages, with 3,342 figures; 8vo, cloth.

All persons interested in crystallized substances will be delighted to know that this monumental work, in the preparation of which Professor Groth spent several decades, has been finally completed. Notices of the publication of the first three volumes have already appeared in SCIENCE.[1] Vol. IV. was issued in 1917 and Vol. V. late in 1919.

According to the original plan it was thought that all the available material could be conveniently published in four volumes; the first two to be devoted to inorganic, and the last two volumes to organic compounds. The aromatic organic compounds, however, proved to be much more numerous than had been

[1] Vol. XXV., 143–144; Vol. XXVIII., 843; Vol. XXXIII., 253.

anticipated, so that two large volumes have been necessary to describe them. These two volumes contain 1,846 pages and 1,783 figures. In these volumes the treatment used in the others has been followed.

Chemists and crystallographers, the world over, are greatly indebted to Professor Groth for this most important reference work, which is a critical survey of all the crystallized material described thus far. As is generally known, Professor Groth has devoted his life to problems in chemical crystallography. He was the founder of and for many years the editor of the *Zeitschrift fuer Krystallographie und Mineralogie*. Hence, he was peculiarly fitted to undertake this very difficult and time-consuming task.

EDWARD H. KRAUS

MINERALOGICAL LABORATORY,
UNIVERSITY OF MICHIGAN

SPECIAL ARTICLES

THE CHANGE IN THE FAT OF PEANUT-FED RABBITS

IN the course of our investigation of the soft pork of peanut-fed hogs it occurred to me that if an animal in starving used its liquid fat first, this would make it possible to overcome the softness of the pork on peanut-fed hogs. If the animal used the liquid fat first in starving it would be reasonable to suppose that if both liquid and solid fat were fed at the same time he would use a greater proportion of the liquid fat to meet the energy requirements of his body. Then it would be possible to attack the soft pork problem in two ways. One would be to feed peanuts alone for forty or fifty days then starve the hog for some eight or ten days so as to remove the liquid fat as much as possible, and afterwards finish the feeding with other feeds. The other way would be to feed the peanuts not alone for forty or fifty days as is the custom but to feed them with some feed that would produce solid fat and in this way the animal would use a greater percentage of the soft fat that was fed than he would otherwise. We got some results this past spring which indicated that it is much better to feed the hogs peanuts with other feeds for seventy days than it is to feed for forty or fifty days with peanuts alone, then to finish with other feeds.

To determine whether an animal in starving uses the liquid fat more rapidly than it does the solid fat, rabbits were fed on peanuts and alfalfa for six weeks. One of the rabbits was killed at the end of the feeding period and the others were killed after starving three, five and seven days. The iodine numbers of the kidney fat and the back fat were determined. Two series of rabbits were treated in this way but the results of the last series only will be given.

Rabbit No.	Iodine Number of Back Fat	Iodine Number of Kidney Fat
1	96.23	98.00
2	78.34	97.92
3	70.98	95.33
4	66.22	92.36

The per cent. of the livers extracted by ether, were rabbit 1, 8.15, rabbit 2, 17.04 rabbit 3, 19.18, rabbit 4, 20.09. It was expected that the ether extract of the livers would increase in starvation and it was thought that the iodine number of this extract would increase but in this last we were disappointed as the iodine number was practically constant, showing the values from 98 to 104.

Our results indicate that the liquid fat of an animal during starvation is used more rapidly than the solid fat, that the liquid fat of the back or subcutaneous fat is used more rapidly than that of the kidney. It is our intention to repeat this work, beginning in about a month, using pigs instead of rabbits.

S. T. DOWELL

OKLAHOMA AGRICULTURAL
EXPERIMENT STATION,
STILLWATER

THE AMERICAN SOCIETY OF MAMMALOGISTS

THE third annual meeting of the American Society of Mammalogists was held in the United States National Museum, Washington, D. C., May 2–4, 1921. Officers elected for the

year are Dr. E. W. Nelson, *president;* Dr. Wilfred H. Osgood and Mr. Gerrit S. Miller, Jr., *vice-presidents;* Dr. H. H. Lane, *recording secretary;* Dr. Hartley H. T. Jackson, *corresponding secretary;* Mr. Arthur J. Poole, *treasurer.* Mr. N. Hollister was reappointed *editor,* and *director ex officio.* The following were elected *directors of the 1921 class:* Dr. Glover M. Allen, Dr. J. Grinnell, Dr. Witmer Stone, Dr. J. C. Merriam, Mr. H. E. Anthony. Upon recommendation by the directors, ninety-nine new members were elected. The Society voted to affiliate with the American Association for Advancement of Science. It also authorized the appointment of a Committee on Marine Mammals to cooperate with the National Research Council or other agencies toward the international preservation of marine mammals.

The following was the program:

MONDAY, MAY 2, 10:00 A.M.

Meeting of the Board of Directors

Afternoon Session, 2:00 P.M.

Remarks on certain mammals of Panama: E. A. GOLDMAN.

A singing mouse: H. H. LANE.

Disposition and intelligence of the orang-utan: W. H. SHEAK.

The California elk-drive of 1904: C. HART MERRIAM.

Some observations on beaver culture with reference to the national forests: SMITH RILEY.

Progress in mammalogy during 1920. General discussion for members, led by T. S. PALMER.

Evening Session, 8:15 P.M.

A motion picture record of the animal collections of the Washington and Philadelphia Zoological Parks. (Made with the camera invented by Carl E. Akeley.) ARTHUR H. FISHER.

TUESDAY, MAY 3

Morning Session, 10:00 A.M.

Geography and evolution as pertaining to the kangaroo rats of California: JOSEPH GRINNELL.

Nerve-endings of the maculæ and cristæ acusticæ: H. H. LANE.

Business Session, 10:45 A.M.

Afternoon Session, 2:00 P.M.

Life histories of African squirrels and related groups: H. LANG.

(a) Meaning of California records for the buffalo: (b) The range of mountain sheep in northern California: C. HART MERRIAM.

Habits of the mammals of Celebes and Borneo: H. C. RAVEN.

WEDNESDAY, MAY 4

Morning Session, 10:00 A.M.

Present status of some of the larger mammals of Canada: R. M. ANDERSON.

Observations on certain specialized structures of the integument of primates. (a) Carpal sinus hairs. (b) A sternal gland in the orang-utan: ADOLPH H. SCHULTZ.

Improved methods of trapping small mammals alive: VERNON BAILEY. (Presented by E. A. GOLDMAN.)

Life-zones of southern Ecuador: H. E. ANTHONY.

Remarks on the distribution and relationships of the North American chipmunks: ARTHUR H. HOWELL.

Some significant features of economic mammalogy: W. B. BELL.

1:00 P.M.

Administration Building, National Zoological Park

Luncheon for members and their wives, as guests of the Administration of the National Zoological Park and the Washington Members.

2:15 P.M.

Final Business Session

2:30 P.M.

Tour of National Zoological Park under direction of N. Hollister, superintendent.

HARTLEY H. T. JACKSON,
Corresponding Secretary